Accounting Tool to Support Federal Reporting of Hydrofluorocarbon Emissions:
SUPPORTING DOCUMENTATION

PREPARED FOR:

Stratospheric Protection Division
Office of Air and Radiation
U.S. Environmental Protection Agency
Washington, D.C. 20460

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Contents

1 Introduction

In 2015, President Obama signed Executive Order (E.O.) 13693 (80 FR 15869),[1] "Planning for Sustainability in the Next Decade," to maintain a sustainability strategy in the federal government and to prioritize greenhouse gas (GHG) emission reductions for federal agencies. E.O. 13693 requires federal agencies to measure and report an annual inventory of GHG emissions for the preceding fiscal year (FY) to the White House Council on Environmental Quality (CEQ) Chair and the Office of Management and Budget (OMB) Director, and to reduce GHG emissions. Agencies must conduct all GHG reporting and inventories in accordance with the CEQ Federal Greenhouse Gas Accounting and Reporting Guidance (CEQ Guidance)[2] and the latest Technical Support Document (TSD).[3] The Department of Energy's (DOE) Federal Energy Management Program (FEMP) in collaboration with the Environmental Protection Agency (EPA), Department of Defense (DoD), General Services Administration (GSA), Department of the Interior (DOI), Department of Corrections (DOC), and other agencies are responsible for preparing and updating the CEQ Guidance. In accordance with E.O. 13693, agencies must include emissions of hydrofluorocarbons (HFCs)—which are extremely potent GHGs—in their reporting. HFCs are commonly used in refrigerators, air conditioners (A/C), and a variety of other applications within federal facilities. The use and emissions of HFCs are growing rapidly as they are increasingly adopted as replacements for ozone-depleting substances (ODS) being phased out under the Clean Air Act (CAA) and as economic growth spurs demand for new equipment, especially in the refrigeration and A/C sector. President Obama's Climate Action Plan (CAP)—announced in June 2013—calls for his Administration to transition to equipment that uses safer and more sustainable alternatives to HFCs.

Federal agencies reported HFC emissions of nearly 2.2 million metric tons of carbon dioxide equivalent in 2010.[4] While the largest federal emitters of HFC emissions have been reporting their emissions, many agencies likely do not have robust systems to collect specific HFC data required for the FEMP Annual GHG and Sustainability Data Report (Excel-based).[5] For refrigerant emissions, the Data Report requires

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[1] The White House, E.O. 13693 of March 19, 2015, *Planning for Federal Sustainability in the Next Decade* accessed on July 15, 2015, https://www.federalregister.gov/articles/2015/03/25/2015-07016/planning-for-federal-sustainability-in-the-next-decade.

[2] CEQ, *Federal Greenhouse Gas Accounting and Reporting Guidance* (Council for Environmental Quality, 2012) accessed on July 7, 2014, http://www.whitehouse.gov/sites/default/files/microsites/ceq/revised_federal_greenhouse_gas_accounting_and_reporting_guidance_060412.pdf.

[3] CEQ, *Federal Greenhouse Gas Accounting and Reporting Guidance, Technical Support Document* (Council for Environmental Quality, 2012) accessed on July 7, 2014, http://www.whitehouse.gov/sites/default/files/federal_greenhouse_gas_accounting_and_reporting_guidance_technical_support_document.pdf.

[4] Data.gov. 2011. *FY2010 Federal Government Greenhouse Gas Inventory by Agency* accessed on August 22, 2014. http://catalog.data.gov/dataset/fy2010-federal-government-greenhouse-gas-inventory-by-agency

[5] FEMP, *Annual GHG and Sustainability Data Report, Version 4.2* (Federal Energy Management Program, 2013) accessed on July 7, 2014, https://www.fedcenter.gov/programs/greenhouse/inventoryreporting/fempceqresources/portal/; this report is to be used by top-tier Federal departments and agencies for comprehensive reporting of annual energy, costs, square footage, and associated operational data. The Data Report is a Microsoft Excel workbook collecting agency-aggregated data necessary for calculating Scope 1, 2, and 3 GHG emissions in the commonly used, native units of energy consumption and fugitive emissions, as well as activity data for estimating Scope 3 indirect emissions. It provides users with the summation of their calculated emissions, as well as the performance results for other energy/sustainability goals.

data by fluorinated gas (F-gas)/refrigerant type[6], and the methodology used to estimate emissions is also performed by F-gas/refrigerant type. This level of detail is often unavailable to reporting leads (e.g., Senior Sustainability Officers, Environmental Program Coordinators), who most likely have anecdotal knowledge of refrigerant-containing equipment at major locations, resulting in potential data gaps and inconsistent year-over-year reporting. Therefore, many agencies may not be reporting HFC emissions due to this lack of data.

To assist agencies in calculating and reporting HFC emissions, EPA developed an Excel-based HFC Emissions Accounting Tool (hereafter referred to as the “HFC Tool”). This HFC Tool provides several approaches for estimating HFC emissions in accordance with CEQ Guidance, depending on the level of information available to each agency about HFC equipment. Federal agencies are not required to use the HFC Tool, but the tool is designed to complement the FEMP Data Report.

In recognition of these HFC reporting challenges, the HFC Tool provides two newly developed approaches that can assist federal agencies in estimating their F-gas emissions by using more readily available data as inputs. These inputs include the square footage of each building, the number of vehicles, or the number and type of refrigeration and A/C equipment owned or operated by an agency. In addition to these two newly developed approaches, the HFC Tool allows federal agencies to estimate HFC emissions from refrigerant-containing equipment using the four existing methods provided in the CEQ Guidance. These existing methodologies include a default material balance methodology and several “advanced” methodologies, which can be found in the CEQ Guidance and TSD and are described below.

In September through October of 2014, the draft HFC Tool and supporting documentation was peer reviewed for its technical content by: Dr. Michael Deru of the National Renewable Energy Laboratory (NREL); Mr. Jed Ela of the General Services Administration (GSA); Ms. Lena Kofas (GSA)[7]; and Mr. Glenn Gallagher of the California Air Resources Board (CARB). The peer reviewers were asked to draw upon their expertise in the buildings sector; expertise in GHG accounting of HFC emissions; and familiarity with Federal sector buildings and data management to comment on whether the equipment assumptions are sound, and whether the approaches and usability of the tool enable potential users to accurately and confidently account for their HFC emissions.

Written comments were received from the peer reviewers. All comments of the reviewers were considered, and the tool and supporting documentation were modified as appropriate.

EPA wishes to acknowledge everyone involved in the development of this report, and to thank the peer reviewers for their time, effort, and expert guidance. The involvement of the peer reviewers greatly

[6] For the purposes of the HFC Tool, fluorinated gases (F-gases) include HFCs and perfluorocarbons (PFCs), another highly potent GHG, for refrigerant applications. While refrigerants largely consist of HFC-based gases, there are some instances of PFC uses.
[7] Jed Ela was the official point of contact in GSA for the peer review, but Lena Kofas also contributed to the review on behalf of GSA per his request.

enhanced the technical soundness of the tool and the supporting document. EPA accepts responsibility for all information presented and any errors contained in this document and the HFC Tool.

This document provides technical documentation to support the HFC Tool. It summarizes the six emission estimation approaches included in the HFC Tool and describes in greater detail the underlying assumptions and calculations used in the two new approaches developed by EPA specifically for inclusion in the tool. The remainder of this document is organized as follows:

- Section 2 describes the capabilities (i.e., calculation approaches, emission calculation data aggregation, and approach comparison) and scope (i.e., timeframe, facilities/regions, calculation limits, equipment and refrigerant types, and reporting boundaries) of the HFC Tool.
- Section 3 describes the existing and new emission estimation approaches available in the HFC Tool to calculate HFC emissions, specifically the equations, data requirements, and default assumptions for each approach.

2 HFC Emissions Accounting Tool Overview

This section summarizes the capabilities and scope of the HFC Tool. Capabilities include the ability to choose from one or more calculation approaches, the ability to aggregate and analyze GHG emissions at multiple levels, and the ability to compare emissions resulting from different calculation approaches for the same emissions source. The scope of the tool describes more of the detailed abilities and limitations of the tool, including the time horizon, number of facilities and emission sources, and available equipment types.

2.1 Summary of Capabilities and Scope

The HFC Tool has the following features and capabilities.

- Compatibility with FEMP Reporting Tool: The HFC Tool allows an agency to generate a report aggregated by refrigerant type that can be transferred directly to the mixed refrigerants input sheet in the FEMP workbook.
- Calculation Approaches: The HFC Tool allows federal agencies to choose from six different approaches to calculate their HFC emissions for reporting purposes (as described further below). The amount of detail needed for each approach varies widely, from building type and square footage, to detailed data of F-gas inventories and equipment capacities. Agencies may choose more than one calculation approach, as they may have different levels of data for different locations or equipment types.
- Aggregating Emissions and Identifying Hotspots: The HFC Tool allows users to calculate F-gas emissions on a mass basis as well as corresponding GHG emissions on a metric ton of carbon dioxide equivalent ($MTCO_2eq$) basis. The tool can be used to aggregate HFC emissions across several different data types, as described in Table 2-1. Federal agencies can generate summary reports to see which locations, building types, equipment types, and refrigerant types are contributing the most to their emissions profile.

Table 2-1. Summary of HFC Emission Aggregation Levels

Data Aggregation Level	Description
Location	User defined facilities or regions
Building Type	Federal building type or vehicle type
Equipment Category	Broad equipment categories (e.g., Room A/C, Residential A/C, and Commercial A/C get aggregated to one group)
Greenhouse Gas Type	Individual HFC types
Equipment Use Stage	Equipment installation, operation, and disposal
Calculation Approach	The six approaches specified in this documentation

- Identifying and Comparing Reduction Opportunities: As a corollary to highlighting HFC emission hotspots, the HFC Tool can also be used to explore reduction opportunities. For instance, for exploratory purposes, users can enter in the same equipment twice using the same calculation approach worksheet, then see what potential reductions can be made by substituting one refrigerant for another refrigerant with a lower global warming potential (GWP).[8]
- Comparing Approaches: Many federal agencies are only just beginning to report on their HFC emissions and may want to explore different calculation approaches. As an exploratory exercise, users of the tool can enter data for the same equipment or building using multiple calculation approaches and compare the resulting emissions. The "Calculation Approach Comparison" report in the "GHG Emissions" sheet is specifically designed to show results for this purpose.

The scope of the HFC Tool is defined by the following:

- Timeframe: Emissions are calculated on an annual basis for a single year only.
- Facilities or regions: Users can define up to 20 facilities or regions to use throughout the tool. If a user has more than 20 facilities, facilities can be aggregated into regions.
- Calculation limits for each approach: There is a limit of 40 distinct entries (rows) per emission estimation approach. Depending on the calculation approach chosen, an individual entry can be a piece of refrigerant-using equipment, or a building or vehicle. If a user has an inventory for more than 40 buildings or pieces of equipment, multiple instances of the same equipment type or building type can be aggregated into one entry, or multiple copies of the tool can be used.
- Equipment types: The HFC Tool includes refrigerant-containing equipment that can be found in both buildings and vehicles. The HFC Tool only calculates emissions of F-gas refrigerants; F-gas emissions from foams, fire protection, solvents, and aerosols are not incorporated into the tool, and the tool also does not cover industrial uses of F-gases.
- Refrigerant types: When identifying the type of refrigerant installed in refrigeration and/or air conditioning equipment, users can either select from a broad list of refrigerants (consistent with the FEMP reporting tool) or select to use a "default" refrigerant, wherein the most commonly used refrigerant in each respective equipment type is provided. The broad list of refrigerants includes those that lead to F-gas emissions, i.e., those that contain HFCs or PFCs in whole or in part; the default refrigerants only assume pure HFCs or HFC blends. Pure ozone-depleting substances (e.g., CFC-12) or natural refrigerants (e.g., ammonia) are not included in the tool, but can be accounted for through the "Non-HFC" refrigerant type.

[8] The global warming potential (GWP) of a gas measures its contribution to radiative forcing (a key driver of climate change) over a period of time on a mass basis compared to a reference gas, carbon dioxide (CO_2). While HFCs make up a small fraction of global GHG emissions on a mass basis, most HFCs have GWPs over a thousand times as powerful as CO_2.

- Reporting boundaries: Agencies should refer to CEQ Guidance[9] for guidance on operational and organizational reporting boundaries. The HFC Tool does not explicitly define the agency boundary, nor provide guidance on boundary choices. Therefore in using the HFC Tool, agencies should be certain that they are only entering data for F-gas use and emissions within their agency boundary.

[9] CEQ, *Federal Greenhouse Gas Accounting and Reporting Guidance* (Council for Environmental Quality, 2012) accessed on July 7, 2014, http://www.whitehouse.gov/sites/default/files/microsites/ceq/revised_federal_greenhouse_gas_accounting_and_reporting_guidance_060412.pdf.

3 HFC Emission Estimation Methodologies

The HFC Tool allows federal agencies to choose from six different approaches for calculating HFC emissions from refrigeration and A/C equipment in the federal sector. Table 3-1 below details the approaches available in the HFC Tool that draw on CEQ Guidance methodologies, and Table 3-2 illustrates the data an agency needs in order to use each approach. As shown, four methodologies are directly sourced from the CEQ Guidance and TSD, while two additional approaches were developed by EPA expressly for inclusion in the HFC Tool.

The four existing approaches are briefly described first in section 3.1, followed by detailed descriptions of the new approaches in section 3.2.

Table 3-1. Summary of HFC Emission Estimation Methodologies

Method Type	Calculation Approach	Description
Existing Approaches from CEQ Guidance Methodologies		
Default	Federal supply system transaction approach	Requires careful tracking of refrigerant purchases/returned (e.g., recovered for recycling/reclamation) including information on the refrigerant type and quantity.
Advanced	Material balance approach	Most thorough; requires data on refrigerant acquisitions, disbursements, inventory, and capacity for each facility.
	Simplified material balance approach	Requires data on types and quantities of refrigerants used to charge new and service existing equipment, recovered from retiring equipment, and capacity of new and retiring equipment.
	Screening approach	Requires inventory of equipment by quantity, equipment category, refrigerant type, and total charge capacity. The user may then use default emission factors and disposal assumptions for each type of equipment or emission event, or customize the calculations with their own emission factors and disposal assumptions.
New Simplified Approaches Developed from the Existing Screening Methodology		
Simplified	Simplified screening 1 approach	Based on existing Screening approach; requires data on inventory of refrigerant-containing equipment by building type/location, equipment category, and quantity.
	Simplified screening 2 approach	Based on existing Screening approach; requires data on federal building type and total square footage of each building type.

Table 3-2. Illustration of Data Required to Calculate HFC Emissions for Each Approach

Data Type	Simplified Screening 2	Simplified Screening 1	Default Methodology Approach	Screening	Simplified Material Balance	Material Balance
General questions regarding building type, equipment type, and number of units/building size						
Building type	✓					
Vehicle category	(Transport)	(Transport)				
Building square feet	✓					
Equipment type for building or vehicle		✓		✓		
Number of vehicles	(Transport)	(Transport)				
Number of refrigerant-containing units		✓				
Refrigerants purchased, used, and recovered						
Amount of refrigerant purchased/issued from supply			✓			✓
Amount of refrigerant returned to the supply system			✓			✓
Amount of refrigerant charged into new equipment				✓		
Amount of refrigerant purchased to fill new equipment at installation					✓	
Amount of refrigerant used to service equipment					✓	
Amount of refrigerant recovered from retiring equipment					✓	
Equipment capacity and refrigerant stocks						
Charge capacity of existing equipment				✓		
Charge capacity of retiring equipment				✓	✓	
Charge capacity of new equipment					✓	
Charge capacity at beginning of the year						✓
Charge capacity at end of the year						✓
Quantity of refrigerant in storage at beginning of year						✓
Quantity of refrigerant in storage at end of the year						✓

3.1 Existing CEQ Guidance Methodologies

As noted above, the HFC Tool includes the four HFC emission calculation approaches drawing directly from the CEQ Guidance and TSD methodologies. The tool calculates F-gas emissions for each approach according to the equations specified in the TSD. These approaches and equations are briefly described below.

3.1.1 Federal Supply System Transaction Approach (Default) Approach

The *Default Methodology* provided in the CEQ Guidance "subtract[s] the quantity of F-gas returned from the quantity an agency purchases or issues to maintain equipment […] as a reasonable estimate of actual emissions." Data necessary for this methodology can be obtained by agency chemical management systems which track requisition, receipt, purchase, storage, issue, shipment and identification of equipment, supply and materials. As noted in the CEQ Guidance, this methodology is most accurate when the charge of F-gas in installed equipment is constant each year; it may lead to an underestimate of emissions if the total charge is declining over time (due to more equipment being disposed of than being installed). For the latter, the CEQ Guidance recommends that agencies use an "advanced" methodology (described further below). The CEQ Guidance further specifies that agencies may choose to calculate a 3-year rolling average base year value for specific F-gas fugitive emissions, or apply an advanced methodology by applying information gathered through record keeping requirements under 40 CFR 82.166 (j) and (k). If a 3-year rolling average base year is used, it must be used for subsequent reporting years.

For the *Default Methodology* approach, annual HFC (F-gas) emissions are calculated using Equation A-13 from the CEQ Guidance:

$$\text{Annual Emissions [MT F-gas]} = (I - R) \cdot 4.536 \times 10^{-4} \text{ [MT/lb]}$$

Where:
I = Amount of F-gas issued from supply system [lb]
R = Amount of F-gas returned to supply system from equipment , which includes the amount recovered from equipment during maintenance and the unused amount originally issued from supply [lb]

Accounting for Negative Emissions

To be consistent with the FEMP Annual GHG and Sustainability Data Report, the HFC Tool allows for the possibility of negative emissions in the *Default Methodology* approach and the *Material Balance* approach. This could occur for instance in the *Default Methodology* if a greater amount of refrigerant is returned to supply than is issued from supply in a given year. Over the years, this negative balance would reverse as the agency would need to be issued a greater amount of refrigerants to service/maintain its equipment. However, if negative emissions do occur in the HFC Tool over the one-year time period, the occurrence is flagged and the user is encouraged to use an advanced emission estimation approach that would render more accurate emission results for the current reporting year, as opposed to year-over-year results.

3.1.2 Material Balance Approach

For the *Material Balance* approach, annual HFC (F-gas) emissions are calculated using Equation A-15 from the CEQ Guidance:

Annual Emissions [MT F-gas] = $(I_B - I_E + P - S + C_B - C_E) \cdot 4.536 \text{ x } 10\text{-}4$ [MT/lb]

Where:
I_B = *Quantity of F-gas in storage at beginning of inventory year [lb]*
I_E = *Quantity of F-gas in storage at end of inventory year [lb]*
P = Sum of all F-gas acquisitions [lb]
S = Sum of all F-gas disbursements [lb]
C_B = *Total capacity of F-gas in equipment at beginning of inventory year [lb]*
C_E = *Total capacity of F-gas in equipment at end of inventory year [lb]*

Example Scenario for the Material Balance Approach:

Agency X has a school with two walk-in refrigeration units that use refrigerant R-404A. At the beginning of the year, agency X had 25 lbs of R-404A in storage outside existing equipment (I_B), and the total charge capacity of the retail food equipment (C_B) was 60 lbs from two units with 30 lbs of charge capacity each. During the year, agency X retired one of the units, recovering 25 lbs to go back into the inventory/storage. They replaced the retiring unit with a similar sized unit and purchased 31 lbs of R-404A (P), all of which was used in charging the new equipment. In addition, agency X used 5 lbs of R-134a to top up existing equipment throughout the year, and no R-404A was sold or returned to supplier (S). At the end of the year, agency X still had 60 lbs of charge capacity for their equipment (C_E); and their records show 45 lbs of R-404A in storage (I_E) since they started with 25 lbs, acquired and then used 31 lbs, topped up equipment with 5 lbs, and recovered 25 lbs.

3.1.3 Simplified Material Balance Approach

For the *Simplified Material Balance* approach, annual HFC (F-gas) emissions are calculated using Equation A-17 from the CEQ Guidance:

Annual emissions [MT F-gas] = $(P_N - C_N + P_S + C_D - R_D) \cdot 4.536 \text{ x } 10^{-4}$ [MT/lb]

Where:
P_N = *Purchases of F-gas used to charge new equipment [lb]*
C_N = *Total full capacity of the new equipment [lb]*
P_S = *Quantity of F-gas used to service equipment [lb]*
C_D = *Total full capacity of retiring equipment [lb]*
R_D = *F-gas recovered from retiring equipment [lb]*

Example Scenario for the Simplified Material Balance Approach:

Agency X has a school with two walk-in refrigeration units that use refrigerant R-404A. Agency X bought new equipment with a charge size of 30 lbs (C_N). 31 lbs of R-404A were bought to fill this equipment (P_N), and thus it is assumed 1 lb is emitted during the installation process. During the year, 5 lbs of R-404A (P_S) were used to service the 60 lbs of existing equipment. Agency X also disposed of equipment with a charge size of 30 lbs of R-404A (C_D). At disposal, 25 lbs of R-404A were recovered (R_D), so the remaining 5 lbs are assumed to be emitted.

3.1.4 Screening Approach

For the *Screening* approach, annual HFC (F-gas) emissions are calculated using Equation A-18 from the CEQ Guidance:

$$\text{Annual Emissions [MT F-gas]} = (C_N \cdot k) + (C \cdot x \cdot T) + (C_D \cdot y \cdot (1- z)) \cdot 4.536 \times 10^{-4} \text{ [MT/lb]}$$

Where:
C_N = *Quantity of F-gas charged into the new equipment [lb]*
C = Total full charge capacity of the equipment [lb]
T = Time equipment was in use [yrs]
C_D = *Total full charge capacity of equipment being disposed [lb]*
k = Installation emission factor [%]
x = Operation emission factor [%]
y = Refrigerant remaining at disposal [%]
z = Recovery efficiency [%]

For this methodology, Table D-7 of the TSD provides default emission factors for refrigeration and A/C equipment for installation, operating, and disposal events. These default emission factors were reviewed and modified for use in the HFC tool based on EPA's best estimates—drawing on the EPA Vintaging Model,[10] recent market research, and expert judgment. The emission factors used in the HFC tool are presented in Table 3-4 below. Users also have the option to override these default emission factors and input their own emission factors into the HFC Tool.

[10] EPA, *Vintaging Model Version 4.4* (Environmental Protection Agency, 2014), "VM IO file_v4.4_10.13.14.xlsx."

EPA's Vintaging Model

The Vintaging Model estimates the annual chemical emissions from industry sectors that have historically used ozone depleting substances (ODS), including A/C, refrigeration, foams, solvents, aerosols, and fire protection. Within these industry sectors, there are over 60 independently modeled end-uses. The model uses information on the market size and growth for each end-use, as well as a history and projections of the market transition from ODS to alternatives. As ODS chemicals are phased out, a percentage of the market share originally filled by the ODS is allocated to each of its substitutes. The model tracks emissions of annual "vintages" of new equipment that enter into operation by incorporating information on estimates of the quantity of equipment or products sold, serviced, and retired or retrofitted each year, and the quantity of the chemical required to manufacture, charge, and/or maintain the equipment. EPA's Vintaging Model uses this market information to build an annual inventory of in-use stocks of equipment and the ODS and non-ODS substitutes in each end-use. The model is updated on a regular basis to reflect changes in the market and new industry information; model assumptions are developed and updated based on information from various sources including industry consultation, market reports and peer-reviewed literature on estimates of the quantity of equipment or products sold, serviced, and retired or retrofitted each year.

Table 3-3. Default F-gas Emission Factors for Refrigeration and A/C Equipment

Equipment Type	Installation Emission Factor [a] k (% of capacity)	Operating Emission Factor x (% of capacity/yr)	Refrigerant Remaining at Disposal y (% of capacity)	Recovery Efficiency z (% of remaining)
Room A/C		0.9%	94%	21%
Other residential A/C and heat pumps		8%	80%	50%
Other commercial A/C and heat pumps		8%	80%	70%
Chillers	0.5%	2%	95%	85%
Household refrigerators and/or freezers		0.5%	91%	31%
Stand-alone retail refrigerators and freezers		1%	90%	25%
Walk-in refrigerators and freezers	2.0%	12%	90%	70%
Supermarket refrigeration and condensing units	2.0%	25%	90%	85%
Medium cold storage	1.0%	25%	80%	80%
Large cold storage	1.0%	25%	80%	80%
Refrigerated transport - land		20%	50%	60%
Refrigerated transport - marine		20%	50%	60%
Passenger car A/C		8.9%	50%	20%
Light-duty or heavy-duty truck A/C		8.9%	50%	20%
Bus A/C		10%	50%	40%

Source: EPA estimates, based on the EPA Vintaging Model Version 4.4, recent market research, and expert judgment.
[a] Applied only to larger equipment that is assumed to be charged on site.
[b] The operating emission factor includes both annual refrigerant leakage from equipment and losses associated with servicing equipment.

Example Scenario for the Screening Approach:

Agency X has a school with two walk-in refrigeration units, both of which use refrigerant R-404A. Since "Walk-in refrigerators and freezers" is chosen from the equipment type list, the associated default leak and disposal rates are populated (k, x, y, z).

Each unit has a charge size of 30 lbs, so there is a 60 lb full charge capacity of the equipment (C). Six months into the year, one unit gets disposed of and replaced by an equivalent 30 lb charge size unit using R-404A, so equipment with a charge size of 30 lbs is disposed of (C_D). Since the new equipment is charged on-site, 30 lbs of R-404A are needed to charge the equipment (C_N). Since 60 lbs of operating equipment was in use for the full year, the time equipment was in use (T) is entered as 1 year so that the full operation emission factor (x) gets applied to refrigerant leaks from equipment.

3.2 New Calculation Approaches Developed for HFC Emissions Accounting Tool

Recognizing some of the information challenges agencies may face, two new HFC emission estimation approaches were developed for inclusion in the HFC Tool. These approaches are based on and use the same equation as the existing *Screening* approach (below) as well as the default emission factors that were revised from those provided in the TSD using ICF expert opinion and EPA's Vintaging Model (presented in Table 3-3 in Section 3.1.4 above). Using Equation A-18 from the CEQ Guidance:

$$\text{Annual Emissions [MT F-gas]} = (C_N \cdot k) + (C \cdot x \cdot T) + (C_D \cdot y \cdot (1 - z)) \cdot 4.536 \times 10^{-4} \text{ [MT/lb]}$$

Where:
C_N = Quantity of F-gas charged into the new equipment [lb]
C = Total full charge capacity of the equipment [lb]
T = Time equipment was in use [yrs]
C_D = Total full charge capacity of equipment being disposed [lb]
k = Installation emission factor [%]
x = Operation emission factor [%]
y = Refrigerant remaining at disposal [%]
z = Recovery efficiency [%]

Compared to the existing Screening approach, however, these two new emission estimation approaches are simplified by requiring less information. As described in the previous section, the existing *Screening* approach requires multiplying the quantity of F-gases by default emission factors for the specific type of equipment or emission event. To use this emission accounting approach, an agency must have an inventory of equipment by quantity, equipment category, F-gas type, and total charge capacity. Consultations undertaken in development of the HFC tool suggested that agencies may not have required information on F-gas type or total charge capacity to use this approach.

Therefore, the two new approaches—*Simplified Screening 1* and *Simplified Screening 2*—rely on basic information about the type and quantity of refrigeration and A/C equipment and the type and square footage of federal buildings, respectively. These new approaches are fully described below.

3.2.1 Simplified Screening 1

To calculate emissions using the equation described in the Screening methodology, the *Simplified Screening 1* approach only requires data on the type and quantity of refrigeration and A/C equipment. From there, the tool applies default assumptions for corresponding F-gas type, total charge capacity, and emission factors for all refrigerant-containing equipment.

Data Requirements

The *Simplified Screening 1* approach requires agency data on the type and number of refrigeration and A/C equipment located in each federal building (Table 3-4). Data on the type of refrigerant being used in each unit of equipment and the building type in which the equipment is located are both optional. If this information is known, it can be input into the tool. Agencies that want to estimate emissions from fleet vehicles must also input data on total number of vehicles by vehicle type.

Table 3-4. Required Data for Simplified Screening 1 Approach

Data	Example(s)
Equipment Type [a]	• Chiller • Household refrigerator and/or freezer • Passenger vehicle air conditioner
Quantity of Equipment. The quantity of refrigerant-containing equipment by equipment type. These data would preferably be known by facility or region.	• Three large cold storage units in a warehouse

[a] Definitions of equipment types are in Appendix B as well as in the 'Definitions' tab of the HFC Tool.

Estimation Approach and Default Assumptions

Table 3-5 below summarizes the approach taken to estimate each of the variables in the emissions equation for the Screening methodology.

Table 3-5. Approaches for Estimating Each Variable in the Emissions Equation

Screening Emissions Equation Variable	Estimation Approach and Default Assumptions
C = Total full refrigerant capacity of the equipment [lb]	User provides data on the equipment type and number of units. Full charge capacity (C) is estimated using assumptions about refrigerant charge size for each equipment type; assumptions are from EPA's Vintaging Model, as presented in Table 3-6 below.
C_N = Quantity of F-gas charged into the new equipment [lb]*	Estimated as an annual value by dividing the refrigerant capacity (C) by the assumed lifetime for each equipment; assumptions about the charge size and lifetime of equipment are from EPA's Vintaging Model, as presented in Table 3-6 below.
C_D = Total full charge capacity of equipment being disposed [lb]*	Estimated as an annual value by dividing the refrigerant capacity (C) by the assumed lifetime for each equipment; assumptions about the charge size and lifetime of equipment are from EPA's Vintaging Model, as presented in Table 3-6 below.
T = Time equipment was in use [yrs]	Assumed to be 1 year. (This variable represents the length of time over which emissions are being accounted, not the age of the equipment). GHG reporting is on an annual basis, so T should never be greater than 1. If equipment is purchased or retired over the year, then T may become less than 1.
k = Installation emission factor [%] x = Operation emission factor [%] y = Refrigerant remaining at disposal [%] z = Recovery efficiency [%]	Based on assumptions in EPA's Vintaging Model, as presented in Table 3-3 above.

*Note: In steady state an equal amount of equipment will be installed and disposed in a given year. Therefore, these two parameters C_N and C_D are equal. Emissions for installation and disposal will still differ due to assumptions on k and z.

To generate emissions for the FEMP report —which requires emissions to be reported by individual F-gas—and to convert emissions from a mass-basis to global warming potential (GWP)-weighted emissions,[11] the HFC Tool applies default assumptions for refrigerant type by equipment type. In addition, these default refrigerants are discounted based on the share of refrigerants that do not contain HFCs. These assumptions can be seen in Appendix D. Assumptions for F-gas type for each type of refrigeration and A/C equipment are derived from EPA's Vintaging Model and presented in Table 3-6 below.

[11] GWPs from the IPCC Second Assessment Report (SAR) and Fourth Assessment Report (AR4) are provided and available for use in the HFC Tool. For reporting year 2014, CEQ guidance requires agencies to report using AR4 GWPs. This is consistent with many other federal GHG programs.

Table 3-6. Default Refrigerant Types and Charge Sizes for Refrigeration and A/C Equipment

Equipment Type	Equipment Charge Size (kg)	Equipment Lifetime (yrs)	Default Refrigerant[a]	Refrigerant F-Gas Composition	GWP (SAR)	GWP (AR4)	Percent Containing HFCs in 2014
Household refrigerators and/or freezers	0.15	14	R-134a	100% HFC-134a	1,300	1,430	100%
Stand-alone retail refrigerators and freezers	0.4	10	R-134a	100% HFC-134a	1,300	1,430	100%
Walk-in refrigerators and freezers	10	20	R-404A	44% HFC-125; 4% HFC-134a; 52% HFC-143a	3,260	3,922	50%
Supermarket refrigeration	1,360	18	R-404A	44% HFC-125; 4% HFC-134a; 52% HFC-143a	3,260	3,922	50%
Refrigerated transport - land	6	12	R-134a	100% HFC-134a	1,300	1,430	100%
Refrigerated transport - marine	6	12	R-134a	100% HFC-134a	1,300	1,430	100%
Medium cold storage	565	25	R-404A	44% HFC-125; 4% HFC-134a; 52% HFC-143a	3,260	3,922	50%
Large cold storage	7,546	25	R-404A	44% HFC-125; 4% HFC-134a; 52% HFC-143a	3,260	3,922	50%
Chillers	500	23	R-134a	100% HFC-134a	1,300	1,430	30%
Room A/C	0.5	12	R-410A	50% HFC-32; 50% HFC-125	1,725	2,088	40%
Other residential A/C and heat pumps	5	15	R-410A	50% HFC-32; 50% HFC-125	1,725	2,088	40%
Other commercial A/C and heat pumps	13	25	R-410A	50% HFC-32; 50% HFC-125	1,725	2,088	30%
Passenger car A/C	0.6	12	R-134a	100% HFC-134a	1,300	1,430	100%
Light-duty or heavy-duty truck A/C	0.8	12	R-134a	100% HFC-134a	1,300	1,430	100%
Bus A/C	5	12	R-134a	100% HFC-134a	1,300	1,430	90%

[a] The HFC default refrigerant is the one assumed to represent the single highest share of installed refrigerants for a particular equipment type according to the U.S. EPA Vintaging Model. Using a combination of refrigerants installed and applying a weighted average GWP was considered, but upon further examination, this approach was shown to have an insignificant impact on emissions, and would have added additional complexity to the tool while implying a false level of precision compared to explicitly using a default refrigerant.
Source: EPA estimates, based on the EPA Vintaging Model Version 4.4, recent market research, and expert judgment.

3.2.2 Simplified Screening 2

To calculate emissions using the equation described in the Screening methodology, the *Simplified Screening 2* approach requires data on the federal building type and total square footage by building type (or total number of vehicles by vehicle type). This approach applies default assumptions for installed refrigerant-containing equipment or total refrigerant capacity, corresponding F-gas type, and emission factors for all equipment.

Data Requirements

The *Simplified Screening 2* approach uses data on the federal building type and total square footage of each building type (Table 3-7). Data on square footage of building space that is not actively utilized (i.e., does not contain refrigeration and A/C equipment, such as a warehouse that is not air conditioned) is optional but can be input.[12] Agencies that want to estimate emissions from fleet vehicles must also input data on total number of vehicles by vehicle type.

Table 3-7. Required Data for Simplified Screening 2 Approach

Data	Example(s)
Building and/or vehicle type[a]	• School • Museum • Passenger car
Total square footage by building type and/or total number of vehicles by vehicle type	• A school with 50,000 sq ft. • A fleet with 500 passenger vehicles, 50 trucks, and 5 buses.

[a] Definitions of building types are in Appendix A as well as in the 'Definitions' tab of the HFC Tool.

Estimation Approach and Default Assumptions

Table 3-8 below summarizes the approach taken to estimate each of the variables in the emissions equation for the Screening methodology.

[12] The HFC Tool makes default assumptions about the types and number of equipment used in each type of building space, as described below and detailed in Appendix C. For example, all building types are assumed to be air conditioned. Thus, if an agency has building space that is not air conditioned and does not contain any refrigerant-containing equipment, the agency may wish to designate this square footage as "not actively utilized."

Table 3-8. Approaches for Estimating Each Variable in the Emissions Equation

Screening Emissions Equation Variable	Estimation Approach and Default Assumptions
C = Total full charge capacity of the equipment [lb]	User provides data on the building and/or vehicle type, and the total building square footage and/or number of vehicles by type. To estimate the full charge capacity (C), the HFC Tool applies default assumptions about the amount of installed refrigerant per unit area (or vehicle), per equipment type for each type of federal building based on its individual refrigeration and A/C needs. These default assumptions are described below, and a complete summary of these assumptions are detailed in Appendix C.
C_N = Quantity of F-gas charged into the new equipment [lb]	Estimated as an annual value by dividing the refrigerant capacity (C) by the assumed lifetime for each equipment; assumptions about the charge size and lifetime of equipment are from EPA's Vintaging Model, as presented in Table 3-6 above.
C_D = Total full charge capacity of equipment being disposed [lb]	Estimated as an annual value by dividing the refrigerant capacity (C) by the assumed lifetime for each equipment; assumptions about the charge size and lifetime of equipment are from EPA's Vintaging Model, as presented in Table 3-6 above.
T = Time equipment was in use [yrs]	Assumed to be 1 year. (This variable represents the length of time over which emissions are being accounted, not the age of the equipment.)
k = Installation emission factor [%] x = Operation emission factor [%] y = Refrigerant remaining at disposal [%] z = Recovery efficiency [%]	Based on assumptions in EPA's Vintaging Model, as presented in Table 3-3 above.

As noted in Table 3-8 above, estimating the full refrigerant charge capacity (C) of a federal building requires the total square footage of building space and the amount of refrigerant per unit area. Federal agencies will be required to provide the total amount of building space and vehicles, and the HFC Tool applies assumptions about the amount of installed refrigerant per unit area for each type of federal building or vehicle based on its individual refrigeration and A/C needs.

The amount of refrigerant installed per equipment, building type, and vehicle type was developed using two approaches (Method A and Method B) depending on the type of information that was available on various equipment and building types, as shown in the table below.

Table 3-9. Approaches Used to Calculate Total Installed Refrigerant in Federal Buildings

Approach	Parameter	Approach	Example Calculation (Total Installed Refrigerant)
Method A	Number of refrigerant-containing equipment units per thousand square feet (units/1,000 ft^2)	The number of units of a specific equipment type per 1,000 ft^2 is multiplied by the typical refrigerant charge size for that equipment and the total square footage. Similar to the *Simplified Screening 1* approach, refrigerant charge size assumptions are based on EPA's Vintaging Model (shown in Table 3-6).	Office building • 50,000 ft^2 • 0.112 household refrigerators/1,000 ft^2 • 0.15 kg/household refrigerator 50,000 ft^2 x 0.112/1,000 ft^2 x 0.15 kg = • 0.84 kg of refrigerant in household refrigerators in office building
Method B	Refrigerant capacity per square foot (kg/ft^2)	The refrigerant capacity per square foot is multiplied by the total square footage.	Supermarkets/Commissaries • 100,000 ft^2 • 0.03 kg refrigerant/ft^2 100,000 ft^2 x 0.03 kg/ft^2 = • 3,000 kg of refrigerant in supermarket refrigeration system

Method A - Number of refrigerant-containing equipment units per thousand square feet

Household Refrigerators and Freezers

State appliance saturation surveys in Massachusetts and California suggest an average of approximately one refrigerator per unit in large multi-unit residential buildings.[13] The average square footage of a U.S. renter-occupied unit (assumed to be a reasonable proxy for federal family housing units) of 1,300 ft^2 was divided by one refrigerator per home to yield **0.769 refrigerators per thousand square feet** of family housing.

The U.S. military adopted a "two plus two" common construction standard in 1995 where two people share a 180 ft^2 room (including closet space).[14] Assuming one compact refrigerator per room yields **5.56 refrigerators per thousand square feet** of dormitories/barracks. It is assumed that a compact refrigerator has a smaller refrigerant charge to that of a normal domestic refrigerator unit.[15]

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[13] ODC, *Massachusetts Residential Appliance Saturation Survey (RASS). Volume 1: Summary Results and Analysis, Table 27* (Opinion Dynamics Corporation 2009), http://www.env.state.ma.us/dpu/docs/electric/09-64/12409nstrd2af.pdf.

[14] The military approved a "one plus one" standard for all military housing which sets a target of providing a single room (no roommate) to all single enlisted personnel by the year 2005, and eventually a shared living room and kitchenette by 2020. This will impact future federal procurement policies of refrigerators, but does not impact the current installed base. Source: Arana-Barradas, Louis A., *Military Dormitories (Barracks)* (Air Force News Service 2014), http://usmilitary.about.com/od/theorderlyroom/l/bldormitories.htm.

[15] Compact refrigerator models identified an R-404A charge size of 1.4 oz (40 g). Source: Summit Compact Refrigerator Models FFAR21L, FF29BK, FFAR22L, and CM405BIADA.

The DOE Medium Office Reference Building model assumes an office building has a total floor area of 53,600 ft^2 with three floors.[16] Assuming two refrigerators are located on each floor, there are **0.112 refrigerators per thousand square feet** of the office building type. This same assumption is also applied to schools and prison and detention centers.

Based on ENERGY STAR Portfolio Manager-published space use information for hospitals, an average of 0.46 staffed hospital beds per 1,000 ft^2 was assumed. Furthermore, one refrigerator per 15 staffed hospital beds was assumed, which is equivalent to 0.067 refrigerators per bed, or **0.031 refrigerators per thousand square feet** of hospitals. The uses of refrigerators are intended to cover all hospital refrigeration uses, such as refrigerators for storing drugs as well as food items.

A typical laboratory module has a minimum width of approximately 10 feet, but this will vary in length based on the number of modules configured in a row, typically ranging up to an ideal length of approximately 33 feet long (National Institutes of Health 2008), or area of 330 ft^2. If one domestic refrigerator exists per laboratory module, there are **3.0 refrigerators per thousand square feet** of laboratories.

Stand-Alone and Walk-In Refrigerators and Freezers

In a given cafeteria, an average of seven stand-alone retail refrigerators and freezers, and three condensing units (used in walk-in refrigerators and freezers) are assumed to be installed. There is assumed to be an average of one cafeteria per school, and one cafeteria per medium-sized hospital. Based on Department of Education school construction guidelines, an average institutional building is approximately 74,671 ft^2. Therefore, for schools, prison and detention centers, and other institutional use buildings, there are seven stand-alone retail refrigerators and freezers and three walk-in refrigerators and freezers per 74,671 ft^2 of building space, or **0.094 stand-alone refrigerators and 0.040 walk-in refrigerators per thousand square feet**. For hospitals, it was assumed that a medium-sized hospital has an average of 200,000 ft^2. Therefore, there are seven stand-alone retail refrigerators and freezers and three walk-in refrigerators and freezers per 200,000 ft^2 of building space, or **0.035 units and 0.015 units per thousand square feet**, respectively. The Simplified Screening 2 approach in the HFC Tool assumes 100% of schools have cafeterias, but it allows users to customize this percentage.

[16] DOE, *Appendix 4A: Characteristics of Medium Office Reference Building Model and Modular Classroom Model* (Department of Energy 2012),http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/app_04_a_nopr_tsd_01_11_2012.pdf.

Method B - Refrigerant capacity per square foot

Supermarket Refrigeration

The HFC Tool's assumptions are based on information about a 117,000-ft^2 commissary operated by the Defense Commissary Agency (DeCA) in San Antonio, Texas, in the community service area of the Lackland Air Force Base. The existing refrigeration system contains approximately 3,390 kg of R-404A, or 0.029 kg (of refrigerant)/ft^2.[17] A typical 60,000-ft^2 supermarket contains approximately 1,590 kg of refrigerant, or 0.027 kg (of refrigerant)/ft^2. Therefore, **supermarkets/commissaries have 0.03 kg (of refrigerant)/ft^2**.

Residential and Commercial A/Cs and Heat Pumps

Assumptions for refrigerant capacity per square foot of building space were developed using ICF expert input. Rules-of-thumb were developed for refrigerant installed in room A/C units, other residential and commercial A/C systems, and chillers per square foot of building space in three building types: offices, hospitals, and warehouses. Based on these rules-of-thumb, further assumptions were developed to apply similar estimates to the remaining building types that are included in the HFC tool. The HFC Tool also includes a table allowing users to customize the share of total square feet for multiple buildings of a certain building type that contains A/C equipment. This is most applicable when a user has A/C for some buildings but not others. Table 3-10 below details the assumptions for refrigerant capacity per square foot for these A/C systems in federal buildings.

Table 3-10. A/C Equipment Refrigerant Capacity per Square Foot in Federal Buildings

Building Type	A/C System Options	Refrigerant Capacity per Square Foot (kg/ft^2)
Office	Room A/C units	0.0018
	Other commercial A/C and heat pumps	
School	Room A/C units	0.0018
	Other commercial A/C and heat pumps	
Family Housing	Room A/C units	0.0018
	Other residential A/C and heat pumps	0.0027
Dormitories/Barracks	Room A/C units	0.0018
	Other residential A/C and heat pumps	0.0027
Post Office	Other commercial A/C and heat pumps	0.0018
Prisons and Detention Centers	Room A/C units	0.0018
	Other commercial A/C and heat pumps	
Museum	Other commercial A/C and heat pumps	0.0018
Other institutional uses	Other commercial A/C and heat pumps	0.0018

[17] ICF, *Application of Climate-Friendly Commercial Refrigeration Technologies: Lackland Air Force Base Commissary* (ICF International 2014). Prepared under EPA Contract Number EP-W-10-031, Task Order 311.

Supermarkets/ commissaries	Other commercial A/C and heat pumps	0.0018
	Chillers	
Warehouse, Service & Industrial	Other commercial A/C and heat pumps	0.0003
	Chillers	
Communications Systems	Other commercial A/C and heat pumps	0.0003
Navigation and Traffic Aids	Other commercial A/C and heat pumps	0.0003
Hospital	Other commercial A/C and heat pumps	0.0023
	Chillers	
Laboratories	Other commercial A/C and heat pumps	0.0023

Source: ICF International assumptions.

Appendix A: Building and Vehicle Types in the HFC Emissions Accounting Tool

Building/Vehicle Type	Description
Office	Buildings primarily used for office space or military headquarters.
School	Buildings primarily used for formally organized instruction, such as schools for dependent children of Federal employees, Indian schools, and military training buildings including specialized training facilities.
Family housing	Buildings primarily used as dwellings for families/dependents. Includes apartment houses, single houses, row houses, public housing, military personnel housing, Federal employee housing, and housing for institutional personnel.
Dormitories/barracks	Buildings primarily used as dwellings for families/dependents. Includes apartment houses, single houses, row houses, public housing, military personnel housing, Federal employee housing, and housing for institutional personnel.
Post office	Buildings or portions of buildings used as a Post Office.
Prisons and detention centers	Buildings used to forcibly contain individuals under the authority of a government, including facilities such as living quarters, kitchen and dining, health care, education, recreation and fitness.
Museum	Buildings used for the housing and/or display of tangible objects or collections for the purpose of displaying said objects or collections for public view and benefit on a regular basis.
Other institutional uses	Buildings used for institutional purposes other than schools, hospitals, and prisons, such as libraries, chapels, out-patient clinics, land ports of entry, and courthouses. This category also includes food preparation and dining facilities, buildings housing entertainment and recreational activities, and visitor's centers.
Supermarkets/commissaries	Buildings used for storing and selling food and supplies and/or a food service establishment.
Warehouse, service & industrial	**Warehouses -** Buildings used for storage, such as ammunition storage, covered sheds, and buildings primarily used for storage of vehicles or materials. Also included are underground or earth covered ammunition storage bunkers and magazines. This category excludes water reservoirs and petroleum, oil, and lubricant (POL) storage tanks which are storage structures. **Service Buildings -** Buildings used for service activities, such as maintenance and repair shops, dry cleaning plants, post exchange stores, airport hangars, and buildings primarily used for vehicle maintenance and repair. **Industrial Buildings -** Buildings specifically designed and primarily used for production or manufacturing, such as the production or manufacture of ammunition, aircraft, ships, vehicles, electronic equipment, fish production, chemicals, aluminum, and magnesium. Included are buildings that house utility plants or utility system components such as pump stations or valves.
Refrigerated warehouse	Buildings used for refrigerated storage that are entirely temperature controlled, primarily used to store perishable, chilled and/or frozen food products or other temperature-sensitive chemicals/products.

Building/Vehicle Type	Description
Communications systems	Buildings used for telephone and telegraph systems, data transmission, satellite communications, and/or associated with radio towers or other communications facilities.
Navigation and traffic aids	Includes buildings that house aircraft or ship navigation and traffic aids, such as beacon lights, antenna systems, ground control approach systems, and obstruction lighting.
Hospital	Buildings used primarily for furnishing in-patient diagnosis and treatment under physician supervision and having 24-hour-a-day registered graduate nursing services. This category also includes medical laboratories used for routine testing. This category excludes buildings used directly in basic or applied medical research.
Laboratories	Buildings used directly in basic or applied research in the sciences (including medicine) and in engineering, such as medical laboratories; meteorological research laboratories; and buildings used in designing, developing, and testing of prototypes and processes for chemistry and physics. This category excludes medical or industrial laboratories used for routine testing.
Refrigerated transport	Refrigerated vehicles that are used to transport perishable goods, such as frozen foods, fruit and vegetables, and temperature-sensitive chemicals.

Appendix B: Equipment Types in the HFC Emissions Accounting Tool

Equipment Type	Description
Room A/C	A self-contained air conditioning unit designed to be window-mounted, portable, or installed through the wall of a room (e.g., window units, packaged terminal A/C [PTAC]). Inside of the unit is a compressor, condensing coil, evaporator coil, blower, controls. Window and wall unit capacities are generally 5,000 to 24,000 BTU/hour, but heavy-duty units can reach 30,000 BTU/hour. PTAC capacities are 7,000 – 15,000 BTU/hr.
Other residential A/C and heat pumps	Other air conditioning systems and heat pumps used in residential buildings, including ducted split systems (central A/C) and ductless split systems (e.g., mini-splits, multi-splits). Capacities are generally less than 65,000 BTU/hr.
Other commercial A/C and heat pumps	Other air conditioning systems and heat pumps used in commercial buildings, including ducted split systems (central A/C), ductless split systems (e.g., variable refrigerant flow systems, other multi-splits), and packaged rooftop units. Capacities are generally 65,000–135,000 BTU/hour for small units and 135,000–240,000 BTU/hour for larger units. Does not include chillers.
Chillers	Centralized air conditioning systems used in medium and large buildings—including offices, hotels, shopping centers, and other large buildings—as well as in specialty applications on ships, submarines, nuclear power plants, and other industrial applications. May use centrifugal, screw, scroll, rotary or reciprocating compressors. Chilled water is typically distributed to heat exchangers, or coils, in air handling units or other types of terminal devices which cool the air in their respective space(s), and then the water is re-circulated back to the chiller to be cooled again. Capacities generally range from 360,000 to 2,400,000 BTU/hr for scroll, screw, rotary and reciprocating compressors and 1,800,000 to 24,000,000 BTU/h for centrifugal compressors.
Household refrigerators and/or freezers	A refrigeration system used for short-term preservation of food products in households which typically has a compression machine designed for continuous automatic operation.
Stand-alone retail refrigerators and freezers	Includes stand-alone retail refrigeration equipment such as reach-in refrigerators and freezers, glass door merchandisers, beverage coolers and water coolers.
Walk-in refrigerators and freezers	Includes walk-in refrigerators and freezers with single or multiple remote condensing unit systems.
Supermarket refrigeration and condensing units	Includes large refrigeration systems used in supermarkets such as systems consisting of racks of multiple compressors and other components that are connected to a remote condenser and linked to display cases, reach-ins, and walk-in cold rooms through a piping network (e.g., centralized, distributed, indirect, or cascade designs).
Medium cold storage	Refrigerated storage rooms or warehouses that are entirely temperature controlled, primarily used to store perishable, chilled and/or frozen food products or other temperature-sensitive chemicals/products. Medium units range from 12,000-120,000 square feet of floor space, or a charge size between 200 and 2,000 lbs.

Equipment Type	Description
Large cold storage	Refrigerated storage rooms or warehouses that are entirely temperature controlled, primarily used to store perishable, chilled and/or frozen food products or other temperature-sensitive chemicals/products. Large units are greater than 120,000 square feet of floor space, or a charge size greater than 2,000 lbs.
Refrigerated transport - land	Refrigerated vehicle that moves products from one place to another on land while maintaining necessary temperatures, and include truck trailers, railway freight cars, and other shipping containers.
Refrigerated transport - marine	Refrigerated ship that moves products from one place to another in a body of water while maintaining necessary temperatures, and includes refrigerated ship holds and other shipping containers.
Passenger car A/C	A light-duty passenger vehicle equipped with an air conditioning system.
Light-duty or heavy-duty truck A/C	A light-duty or heavy-duty truck equipped with an air conditioning system.
Bus A/C	A bus equipped with an air conditioning system.

Appendix C: *Simplified Screening 2* Approach Assumptions

Building or Vehicle Type	Equipment Type	Units per Thousand Square Feet	Refrigerant Capacity per Square Foot (kg/ft^2)	Refrigerant Charge Size per Unit of Equipment (kg)	# of Units of Equipment	Variable Name	Square Feet for Variable
Office	Household refrigerators and/or freezers	0.112		0.15	6	per building (2 refrigerators per floor, 3 floors)	53,600
	Other commercial A/C and heat pumps		0.0018	13	1.4	per building	10,000
School	Household refrigerators and/or freezers	0.112		0.15	See Office	See Office	See Office
	Stand-alone retail refrigerators and freezers	0.094		0.4	7	per cafeteria (assumes 1 cafeteria per school)	74,671
	Walk-in refrigerators and freezers	0.04		10	3	per cafeteria (assumes 1 cafeteria per school)	74,671
	Other commercial A/C and heat pumps		0.0018	13	See Office	See Office	See Office
Family Housing	Household refrigerators and/or freezers	0.769		0.15	1	per apartment (in large multi-unit residential building)	1,300
	Average room A/C & Other residential A/C and heat pumps		0.00225	2.75	8.2	per building (average of room A/C units and other residential/heat pumps)	10,000
Dormitories/ Barracks	Household refrigerators and/or freezers[a]	5.56		0.04	1	per dorm room	180
	Average room A/C & Other residential A/C and heat pumps		0.00225	2.75	See Family Housing	See Family Housing	See Family Housing
Post Office	Other commercial A/C and heat pumps		0.0018	13	See Office	See Office	See Office

Building or Vehicle Type	Equipment Type	Units per Thousand Square Feet	Refrigerant Capacity per Square Foot (kg/ft^2)	Refrigerant Charge Size per Unit of Equipment (kg)	# of Units of Equipment	Variable Name	Square Feet for Variable
Prisons and Detention Centers	Household refrigerators and/or freezers	0.112		0.15	See Office	See Office	See Office
	Stand-alone retail refrigerators and freezers	0.094		0.4	See School	See School	See School
	Walk-in refrigerators and freezers	0.04		10	See School	See School	See School
	Other commercial A/C and heat pumps		0.0018	13	See Office	See Office	See Office
Museum	Other commercial A/C and heat pumps		0.0018	13	See Office	See Office	See Office
Other institutional uses	Stand-alone retail refrigerators and freezers	0.094		0.4	See School	See School	See School
	Walk-in refrigerators and freezers	0.04		10	See School	See School	See School
	Other commercial A/C and heat pumps		0.0018	13	See Office	See Office	See Office
Supermarkets/ Commissaries	Supermarket refrigeration and condensing units		0.03	1,360	2.5	per typical supermarket	60,000
	Other commercial A/C and heat pumps		0.0018	13	See Office	See Office	See Office
Warehouse, Service & Industrial	Other commercial A/C and heat pumps		0.0003	13	0.2	per building	10,000
Refrigerated Warehouse	Cold storage		0.0075	565	--	Assumptions are from EPA's Vintaging Model	--
Communications Systems	Other commercial A/C and heat pumps		0.0003	13	See Warehouse, Service, and Industrial	See Warehouse, Service, and Industrial	See Warehouse, Service, and Industrial

Building or Vehicle Type	Equipment Type	Units per Thousand Square Feet	Refrigerant Capacity per Square Foot (kg/ft^2)	Refrigerant Charge Size per Unit of Equipment (kg)	# of Units of Equipment	Variable Name	Square Feet for Variable
Navigation and Traffic Aids	Other commercial A/C and heat pumps		0.0003	13	See Warehouse, Service, and Industrial	See Warehouse, Service, and Industrial	See Warehouse, Service, and Industrial
Hospital	Household refrigerators and/or freezers	0.031		0.15	1	per 15 staffed hospital beds	(and 0.46 beds per 1,000 square feet)
	Stand-alone retail refrigerators and freezers	0.035		0.4	7	per cafeteria (assumes 1 cafeteria per medium-sized hospital)	200,000
	Walk-in refrigerators and freezers	0.015		10	3	per cafeteria (assumes 1 cafeteria per medium-sized hospital)	200,000
	Chillers		0.0023	500	1	per building	200,000
Laboratories	Household refrigerators and/or freezers	3		0.15	1	per laboratory module	330 (10ft x 33 ft)
	Other commercial A/C and heat pumps		0.0023	13	1	per building	10,000
Mobile	Refrigerated transport - land			6	N/A	N/A	N/A
	Refrigerated transport - marine			6	N/A	N/A	N/A
	Passenger car A/C			0.6	N/A	N/A	N/A
	Light-duty or heavy-duty truck A/C			0.8	N/A	N/A	N/A
	Bus A/C			5	N/A	N/A	N/A

[a] Compact refrigerators are assumed to be installed in dormitories/barracks, therefore the charge size (0.04 kg) is smaller relative to standard household refrigerators (0.15 kg).

Appendix D: Default Percentage of Units That Use HFCs by End-use and Year

Reporting Year	Household refrigerators and/or freezers	Room A/C	Other commercial A/C and heat pumps	Other residential A/C and heat pumps	Medium cold storage	Large cold storage	Chillers	Stand-alone retail refrigerators and freezers
2010	100%	10%	10%	20%	30%	30%	20%	100%
2011	100%	20%	20%	20%	40%	40%	20%	100%
2012	100%	30%	20%	30%	40%	40%	30%	100%
2013	100%	30%	30%	30%	50%	50%	30%	100%
2014	100%	40%	30%	40%	50%	50%	30%	100%
2015	100%	50%	40%	50%	60%	60%	40%	100%
2016	100%	60%	50%	50%	60%	60%	40%	100%
2017	100%	70%	50%	60%	60%	60%	50%	90%
2018	100%	80%	60%	70%	70%	70%	50%	90%
2019	100%	90%	70%	70%	70%	70%	60%	90%
2020	100%	100%	70%	80%	70%	70%	60%	80%
2021	100%	100%	80%	90%	70%	70%	60%	80%
2022	100%	100%	90%	90%	80%	80%	70%	80%
2023	100%	100%	100%	100%	80%	80%	70%	70%
2024	100%	100%	100%	100%	80%	80%	80%	70%
2025	100%	100%	100%	100%	80%	80%	80%	70%
2026	100%	100%	100%	100%	80%	80%	80%	70%
2027	100%	100%	100%	100%	90%	90%	90%	70%
2028	100%	100%	100%	100%	90%	90%	90%	70%
2029	100%	100%	100%	100%	90%	90%	90%	70%
2030	100%	100%	100%	100%	90%	90%	90%	70%

Reporting Year	Walk-in refrigerators and freezers	Supermarket refrigeration and condensing units	Refrigerated transport - land	Refrigerated transport - marine	Passenger car A/C	Light-duty or heavy-duty truck A/C	Bus A/C
2010	30%	40%	100%	100%	100%	100%	70%
2011	30%	40%	100%	100%	100%	100%	70%
2012	40%	50%	100%	100%	100%	100%	80%
2013	50%	50%	100%	100%	100%	100%	80%
2014	50%	50%	100%	100%	100%	100%	90%
2015	60%	60%	100%	100%	100%	100%	90%
2016	60%	60%	100%	100%	100%	100%	90%
2017	70%	70%	100%	100%	100%	100%	100%
2018	70%	70%	100%	100%	90%	90%	100%
2019	70%	70%	100%	100%	90%	90%	100%
2020	80%	80%	100%	100%	80%	80%	100%
2021	80%	80%	100%	100%	70%	80%	100%
2022	80%	90%	100%	100%	70%	70%	100%
2023	90%	90%	100%	100%	60%	60%	100%
2024	90%	90%	100%	100%	50%	60%	100%
2025	90%	100%	100%	100%	50%	50%	100%
2026	90%	100%	100%	100%	40%	50%	100%
2027	100%	100%	100%	100%	40%	40%	100%
2028	100%	100%	100%	100%	30%	30%	100%
2029	100%	100%	100%	100%	30%	30%	100%
2030	100%	100%	100%	100%	20%	20%	100%

Source: EPA, *Vintaging Model Version 4.4* (Environmental Protection Agency, 2014), "VM IO file_v4.4_10.13.14"; model values have been rounded.